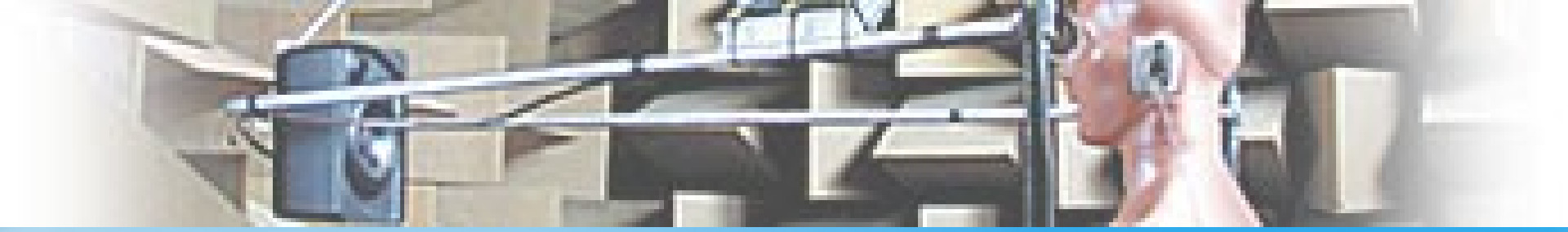


QuickSIN™ Speech-in-Noise Test: Use in Determining Auditory Fitness for Duty

Patty Niquette, M.A.

The 45th Navy Occupational Health and Preventive Medicine Conference

March 21, 2006

ETYMŌTIC RESEARCH INC.

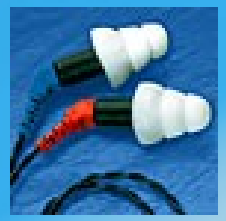
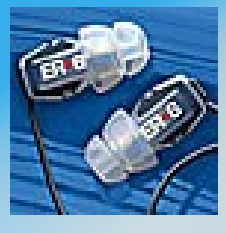
Etymotic Research, Inc.

- Mission: *to design high-fidelity products to measure, improve and protect hearing.*
  -Patents:
  89 issued; 61 pending
- Sponsorship of research

ETYMŌTIC RESEARCH INC.

Consumer Products Division

- High-fidelity, noise-isolating earphones
  - ER-4 MicroPro™ series
  - ER-6 Isolator™ series
  - 6i Isolator™
  - Does Earphone type affect hearing risk?

- High-fidelity, noise-isolating handsfree cellphone headset: ETY•COM™
  - Highest noise isolation of any cellphone headset

ETYMŌTIC RESEARCH INC.

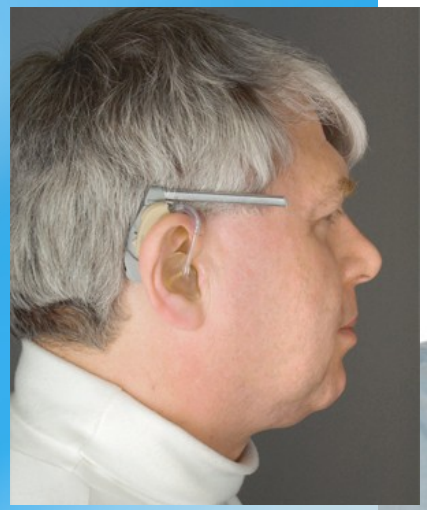
Audiology Division

- Instrumentation for:
  - Audiometry
  - Auditory research
  - Infant hearing screening
  - Otoacoustic emissions
  - ABR
  - Real-ear measurement
  - Personal noise dosimetr

ETYMOTIC RESEARCH INC.

Audiology Division

- High-fidelity, low-distortion hearing aid circuitry
  - K-AMP™
  - Digi-K™



- SNR-Enhancing Technologies
  - Directional microphones (D-MIC, CC-MIC)
  - Array microphones (Linkit™)
  - Companion Mics™ System

ETYMŌTIC RESEARCH INC.

Companion Mics™ System

- One receiver; one to four transmitters
- 15-20 dB > SNR with all mics open
- Listener uses earphones or neck loop (t-coil)

ETYMOTIC RESEARCH INC.

Audiology Division

- High-fidelity hearing protection
  - Musicians Earplugs™
  - ETY•Plugs™

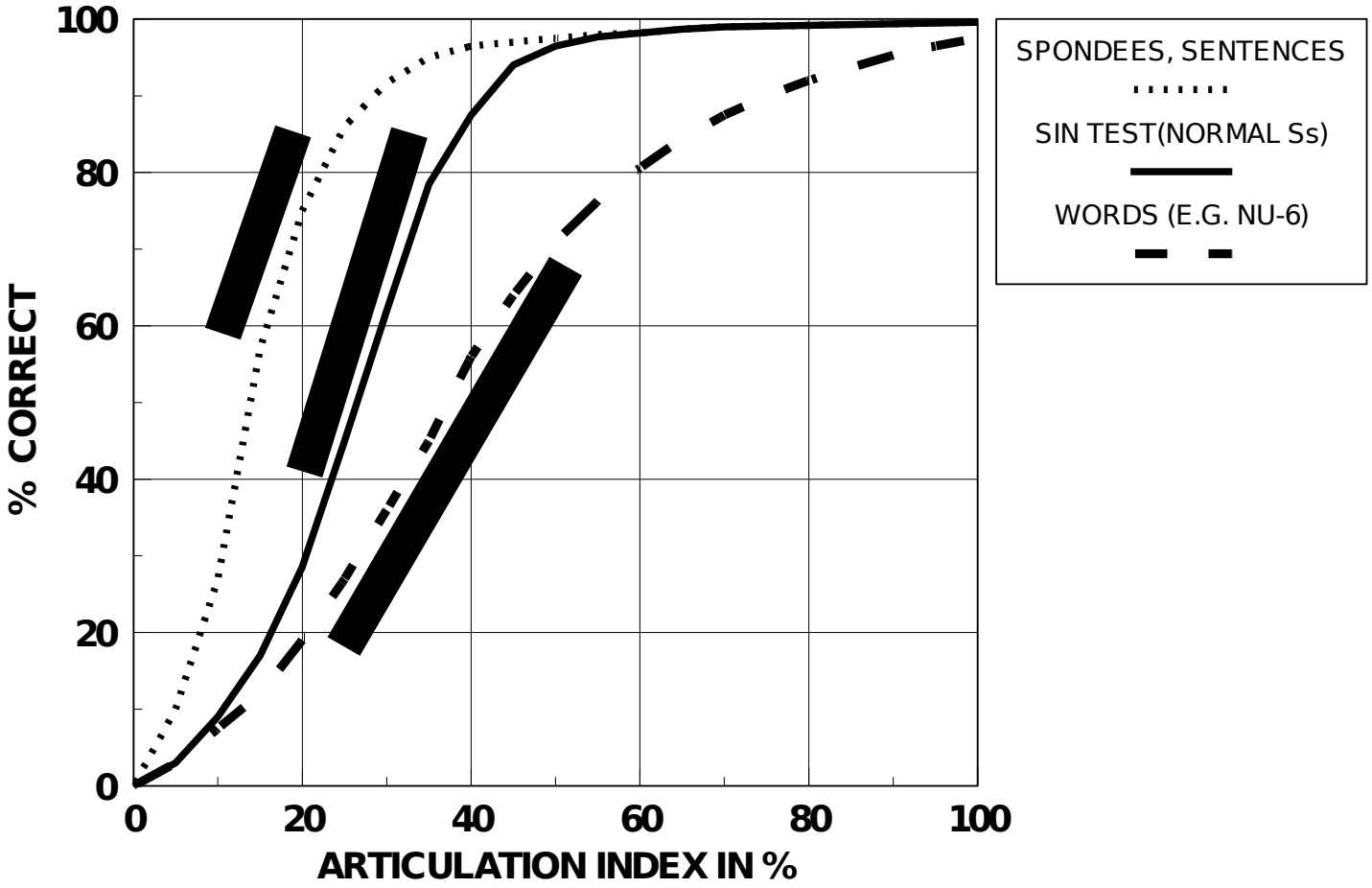
- Speech-in-Noise Tests
  - QuickSIN™
  - BKB-SIN™
  - R-SPACE ™

ETYMOTIC RESEARCH INC.

Hearing In Noise

- MarketTrak: two-thirds of hearing aids user are dissatisfied with hearing aids in noisy environments (Kochkin, 1992; 1993; 1995; 1996; 2000; 2002)
- Speech intelligibility in noise is still the #1 improvement sought in hearing aids (Kochkin, 2003)
- Fitness for duty and hearing-critical jobs
  - What does the person need to hear?
  - Under what conditions?
  - What are the possible ramifications?

Intelligibility of Words and Sentences vs. Articulation (Audibility) Index



ETYMŌTIC RESEARCH INC.

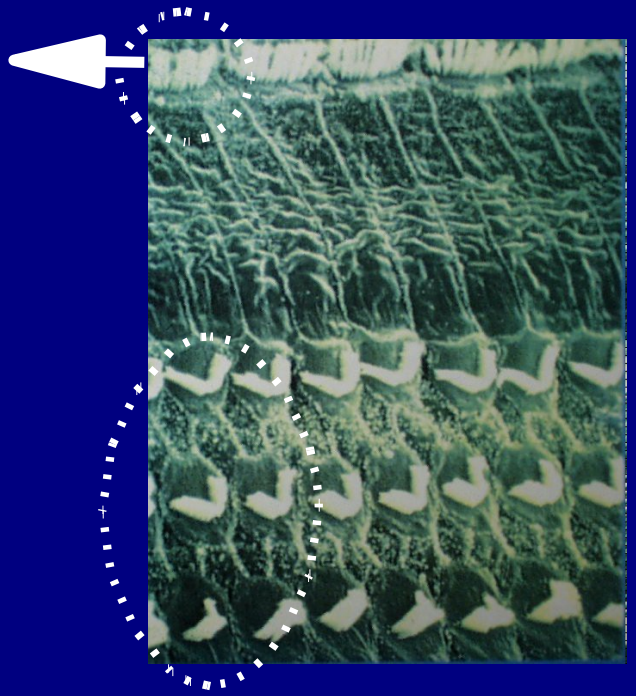
Is 50% Correct Good Enough?

Aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn’t mttaer in what oredr the ltteers in a wrod are, the olny iprmoetnt tihng is that the frist and lsat ltteer be at the rghit pclae. The rset can be a ttoal mses and you can still raed it wouthit a porbelm. Tihs is bcuseae we do not raed ervey lteter by istlef, but the wrod as a wlohe.

ETYMŌTIC RESEARCH INC.

inner hair cells (ihc)

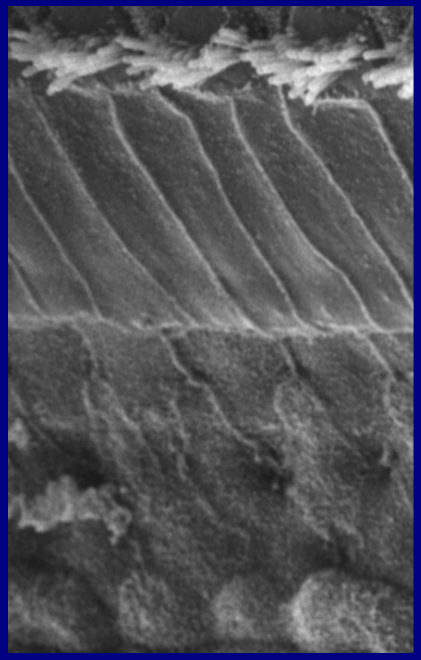
SEND NEURAL PULSES TO THE BRAIN



outer hair cells (ohc)

MOTION AMPLIFIERS

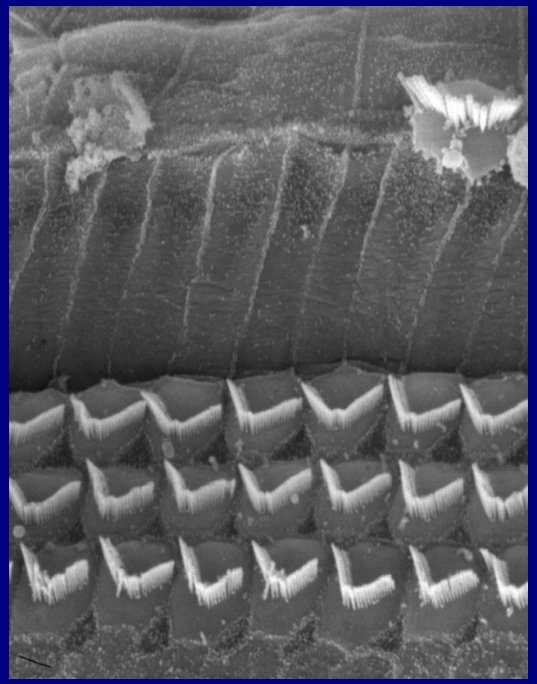
(a) NORMAL HEARING



(b) SENSITIVITY LOSS

OUTER HAIR CELLS MISSING;

IHCs OK



(c) CLARITY LOSS

INNER HAIR CELLS MISSING;

OHCs OK

a) NHCA

b), c) Bob Harris

Two Aspects of Hearing In Noise

- Hearing Loss (HL on the audiogram) is the increased dB SPL required to hear a tone, relative to normal

- SNR Loss is the increased dB signal-to-noise ratio required to understand speech, relative to normal

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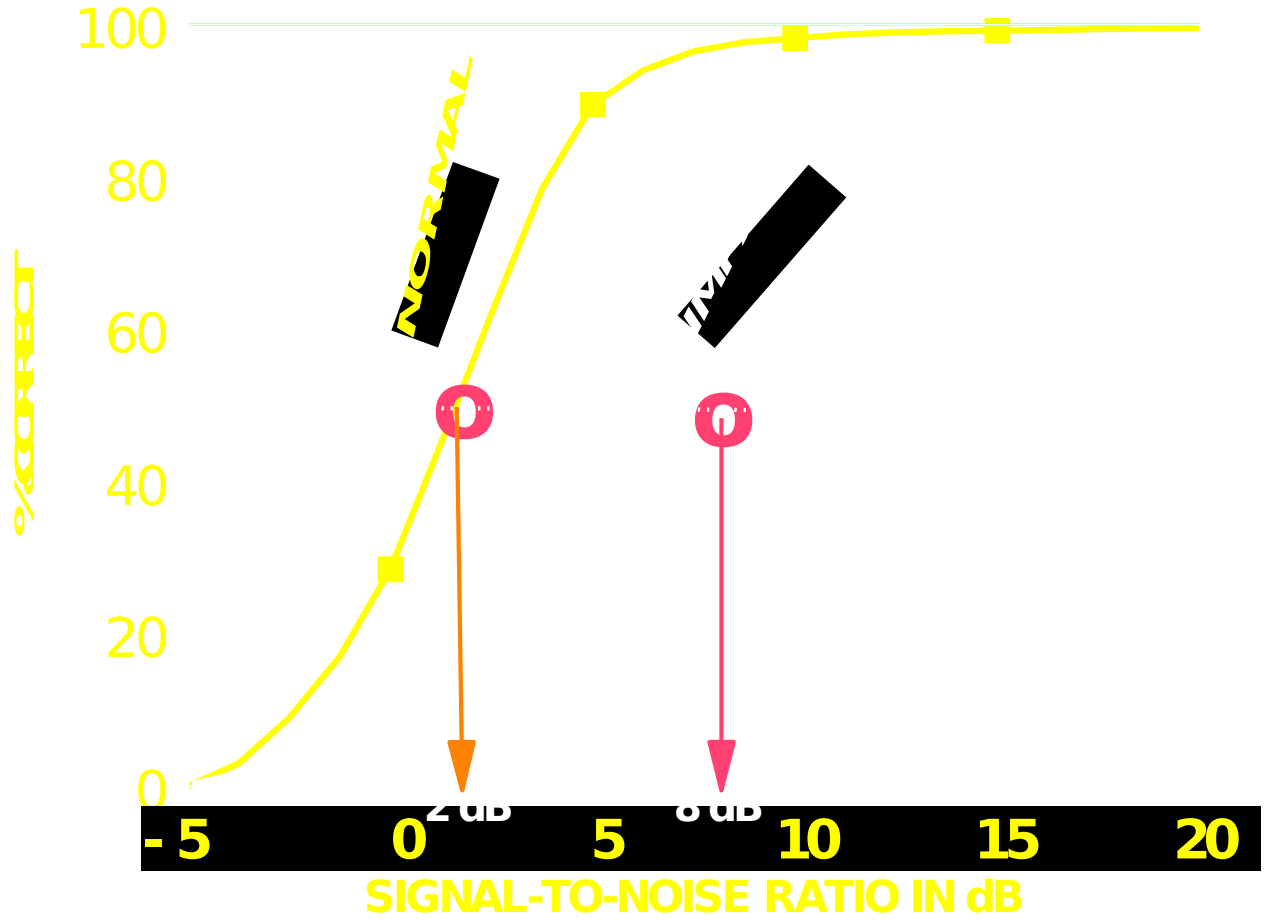
OBTAINING SNR LOSS

DIFFERENCE IN SNRs FOR 50% CORRECT



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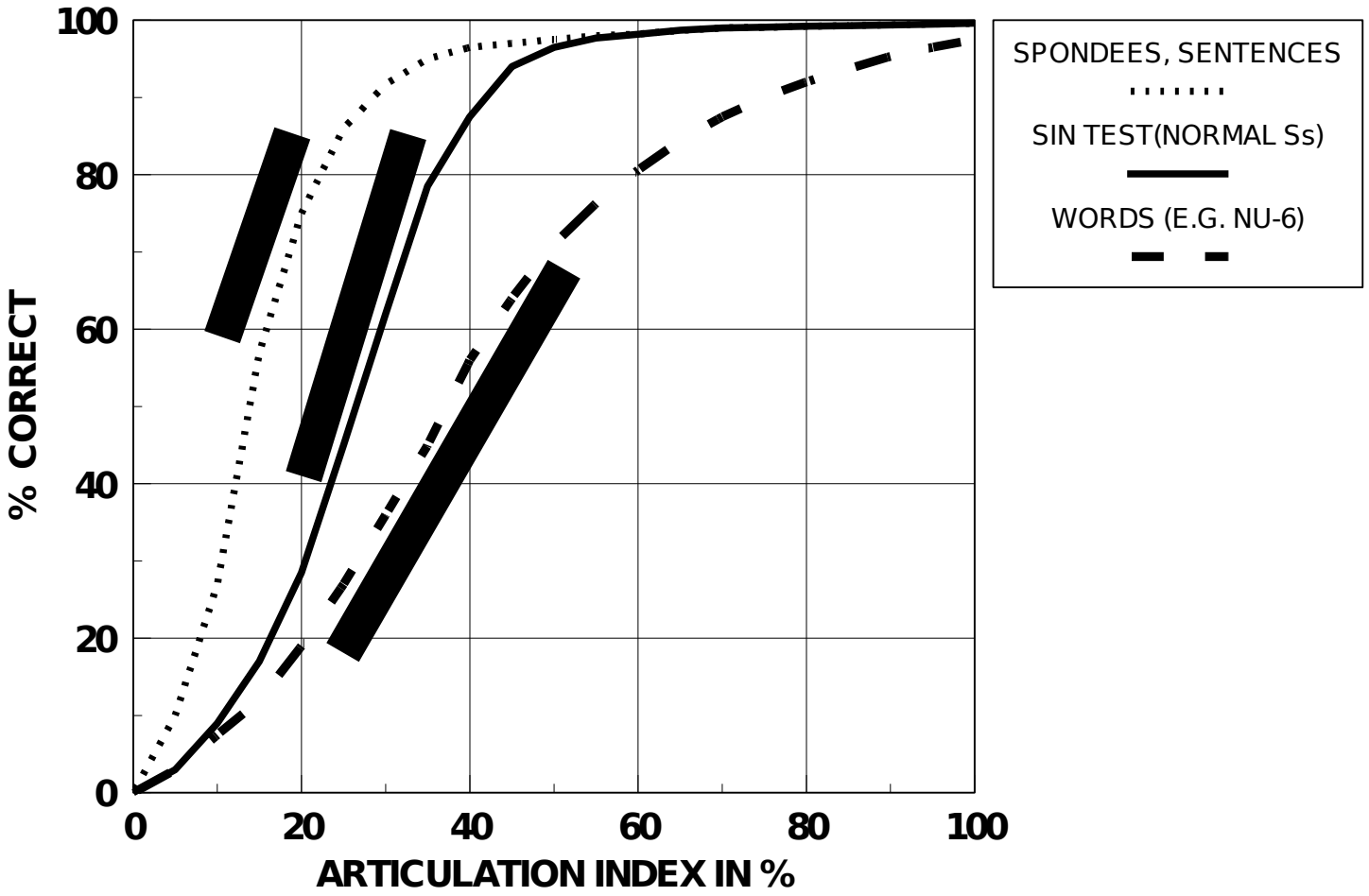
Intelligibility of Words and Sentences vs. Articulation (Audibility) Index



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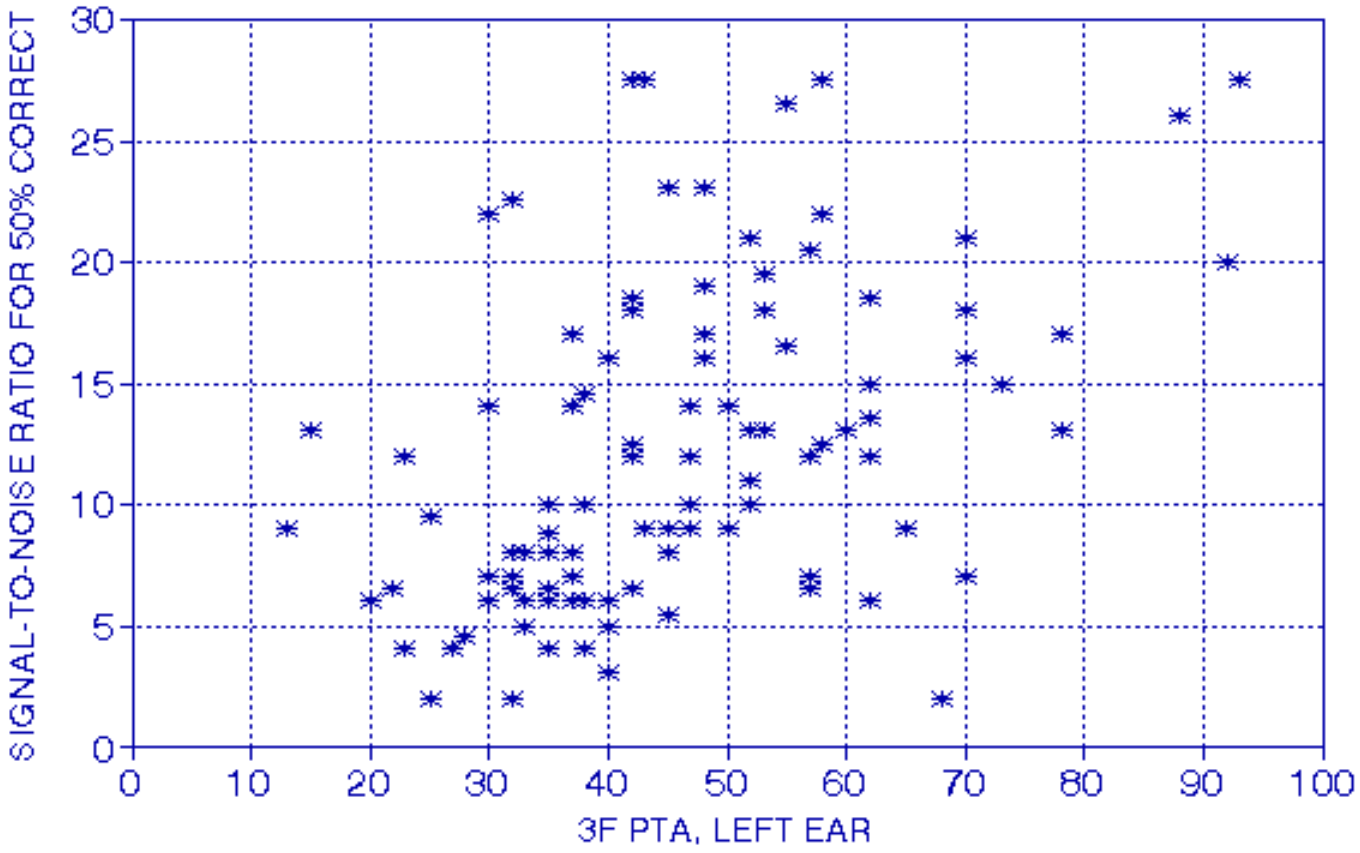

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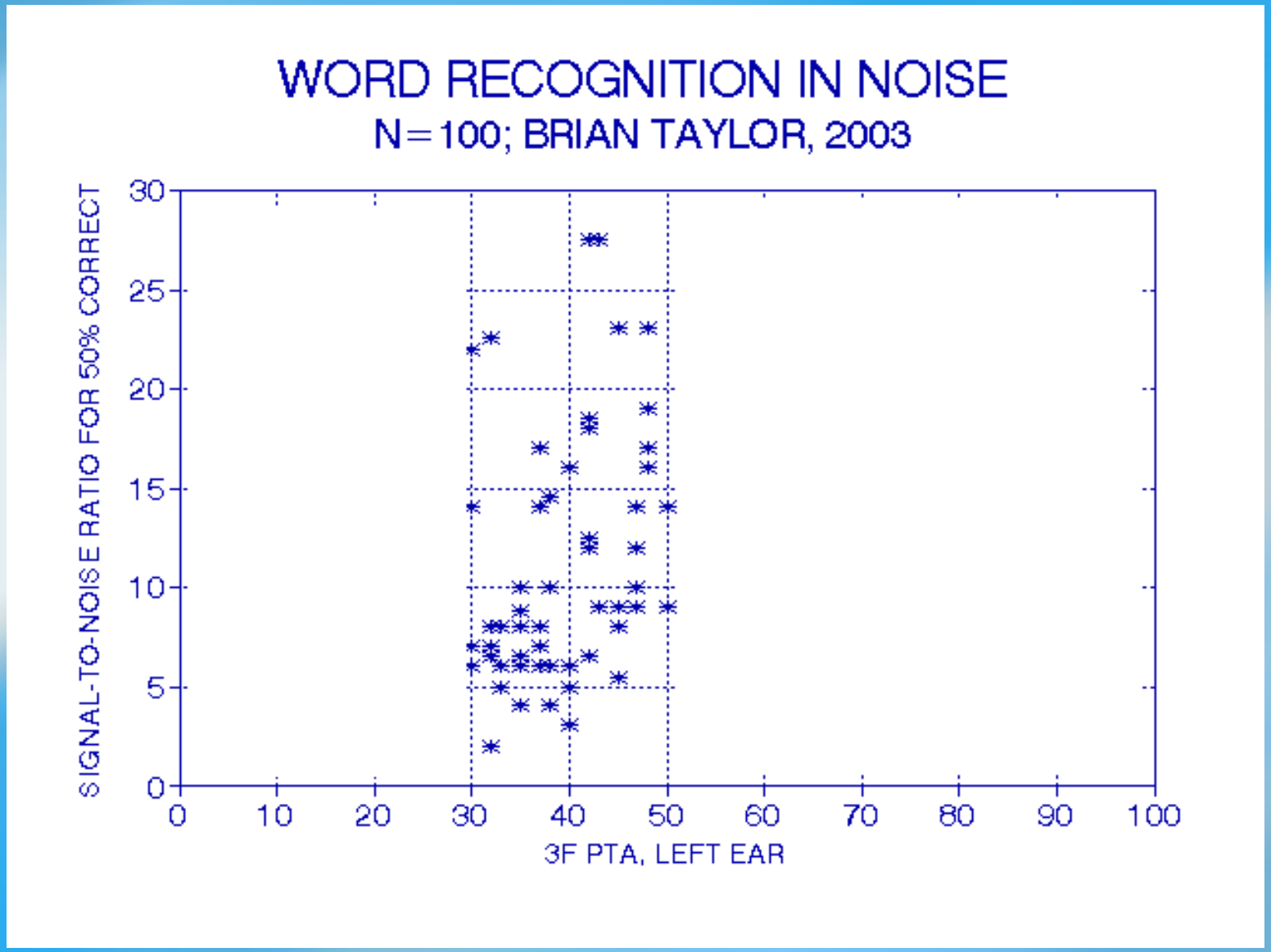

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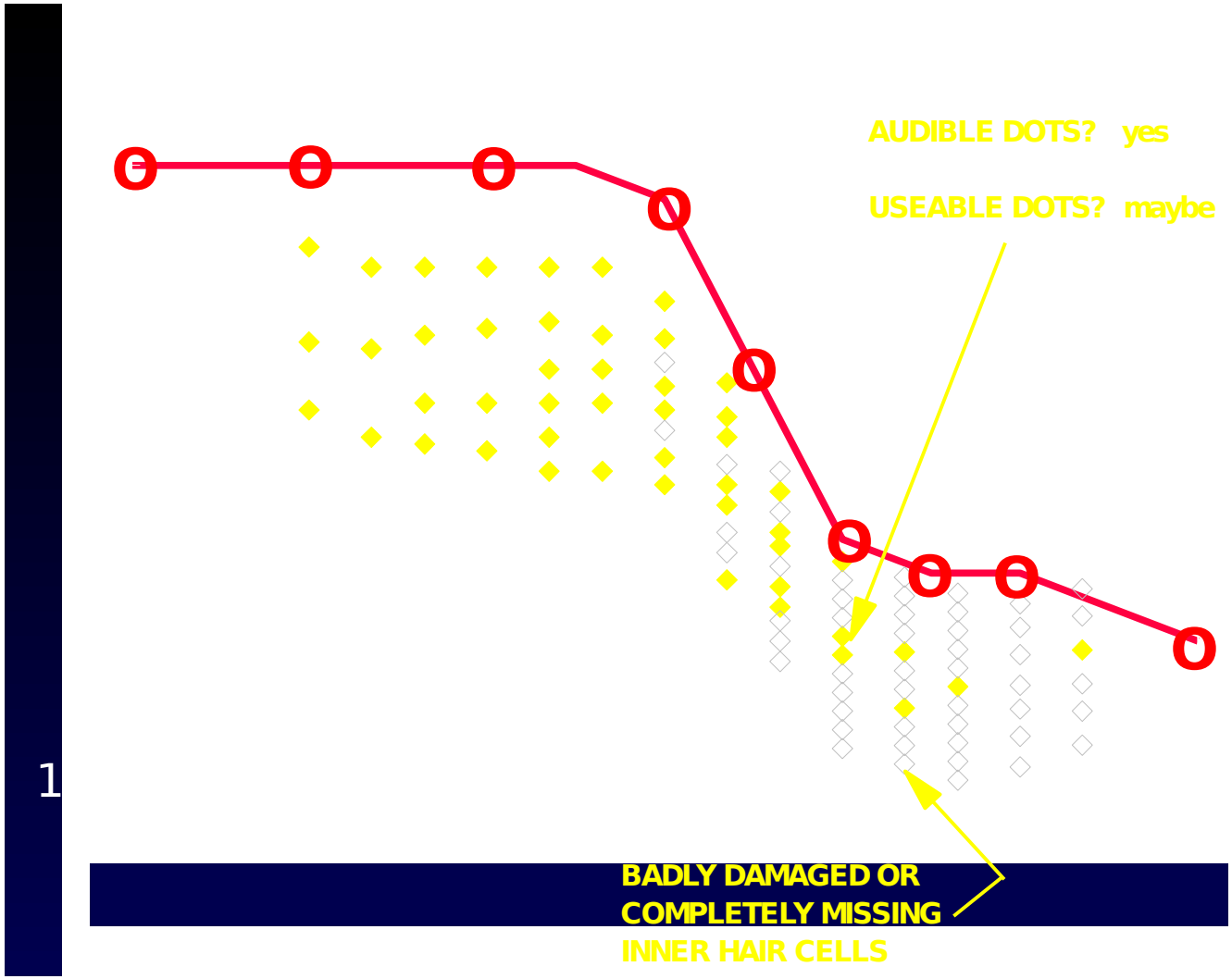
HOW MANY SPEECH CUES MAY BE *AUDIBLE* BUT NOT *UNDERSTANDABLE*?



ETYMŌTIC RESEARCH INC.

ER's R & D Efforts

- Provide a way to rapidly estimate an individual's ability to hear in noise
  - QuickSIN™
  - BKB-SIN™
- Replicate real-world conditions as closely as possible in a controlled laboratory setting
  - R-Space™

ETYMŌTIC RESEARCH INC.

Factors Affecting Performance on Any Speech-in-Noise Test

- Speech materials used (sentences, spondees, etc.)
- Background noise (shaped noise, multi-talker babble)
- Test setup (sp/noise at 0°vs. sp/noise separated)
- Audibility
- Reverberation
- Knowledge of the language
- Age

ETYMŌTIC RESEARCH INC.

Speech-in-Noise Test Construct: “Target Speech” Considerations

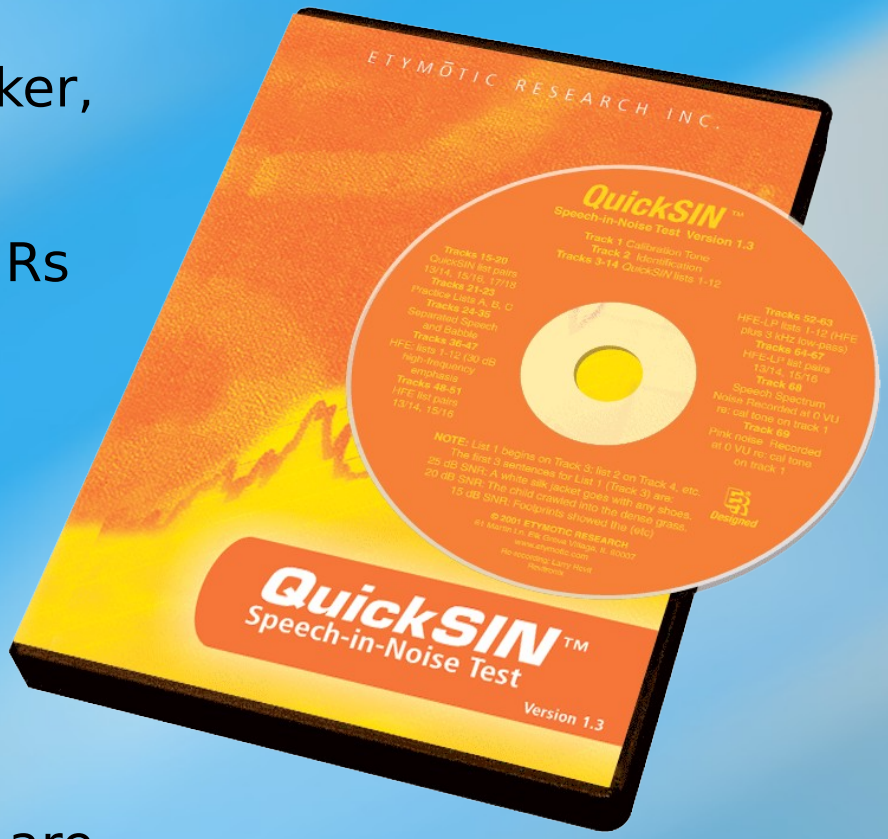
- Monosyllabic words are not “real” speech
  - Sentences spoken with natural dynamics have greater dynamic range than monosyllabic words, and are a more valid representation of real speech
  - “Precompressed” speech is not natural
  - Sentence tasks can be efficient if a words-in-sentences scoring paradigm is used

Speech-in-Noise Test Construct: Background Noise Considerations

- Speech-shaped noise is easier to control, but…
  - It doesn’t reflect amplitude and temporal characteristics of real speech
  - Results don’t necessarily generalize to the real world, especially for hearing aids that utilize compression
  - Patients rarely say that shaped noise sounds like background noise in the real world
- Auditec four-talker babble (3 females, 1 male) = realistic simulation of a social gathering
  - What the person wants to hear is speech, and what they don’t want to hear is *also* speech

QuickSIN™ Test (2001):

- IEEE sentences, female talker, in 4-talker babble
- 1 sentence at each of 6 SNRs (25, 20, 15, 10, 5, 0)
- Scoring: SNR Loss = 25.5 – Total Correct
- 12 equivalent lists; each takes 1 minute
- 3 additional list pairs for research, where more lists are needed



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“Standard” QuickSIN

- Speech and noise are presented together at prerecorded signal-to-noise ratios
- Present the test through headphones
  - Monaural or binaural
  - 70 dB HL (for losses greater than 45 dB HL, present test at “loud but OK”)
  - One practice list, two to three test lists

ETYMŌTIC RESEARCH INC.

Instructions

- Imagine you are at a party. There will be a woman talking and several other talkers in the background. The woman's voice is easy to hear at first, because her voice is louder than the others. Repeat each sentence the woman says. The background talkers will gradually become louder, making it difficult to understand the woman's voice, but please guess and repeat as much of each sentence as possible.

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QuickSIN Example

List 5 S/N	Score	
1. To have is better than to wait and hope.	25	____
2. The screen before the fire kept in the sparks.	20	____
3. Thick glasses helped him read the print.	15	____
4. The chair looked strong but had no bottom.	10	____
5. They told wild tales to frighten him.	5	____
6. A force equal to that would move the earth.	0	____
	Total	____

25.5 – Total Correct = SNR Loss

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QuickSIN Demo

		SNR	Correct
1.	To have is better than to wait and hope.	25	5
2.	The screen before the fire kept in the sparks.	20	5
3.	Thick glasses helped him read the print.	15	4
4.	The chair looked strong but had no bottom.	10	3
5.	They told wild tales to frighten him.	5	1
6.	A force equal to that would move the earth.	0	0

Total Correct = 18

SNR Loss = 25.5 – 18 = 7.5

ETYMŌTIC RESEARCH INC.

Interpreting SNR Loss

SNR Loss	Category	Technology Needs
0-3 dB	Normal	Omni or Directional Mics
3-7 dB	Mild	Directional Mics
7-15 dB	Moderate	Array Mic
>15 dB	Severe	FM or Comp. Mics

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QuickSIN Statistics: Reliability

Number of Lists	1	2	3	4	5	6	7	8
95% C.I. ±, in dB	2.7	1.9	1.6	1.4	1.2	1.1	1.0	1.0
90% C.I. ±, in dB	2.2	1.6	1.3	1.1	1.0	0.9	0.8	0.8
80% C.I. ±, in dB	1.8	1.3	1.0	0.9	0.8	0.7	0.7	0.6

ETYMŌTIC RESEARCH INC.

“Split-track” QuickSIN (separated speech & babble)

- Can be used to verify effectiveness of directional microphones in SF
- Speech and babble separated
  - Calibrate both channels
    - Target talker = Channel 1
    - 4-talker babble = Channel 2
  - Examiner sets presentation levels

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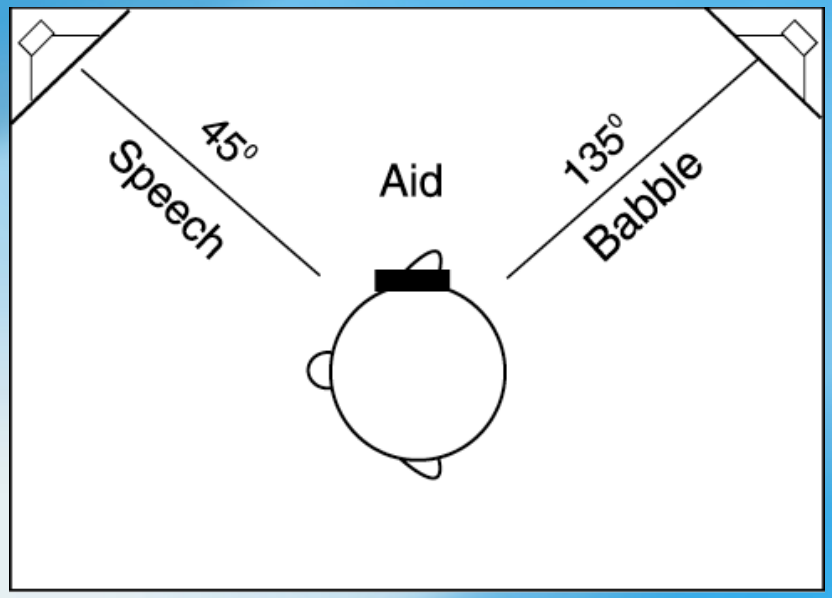
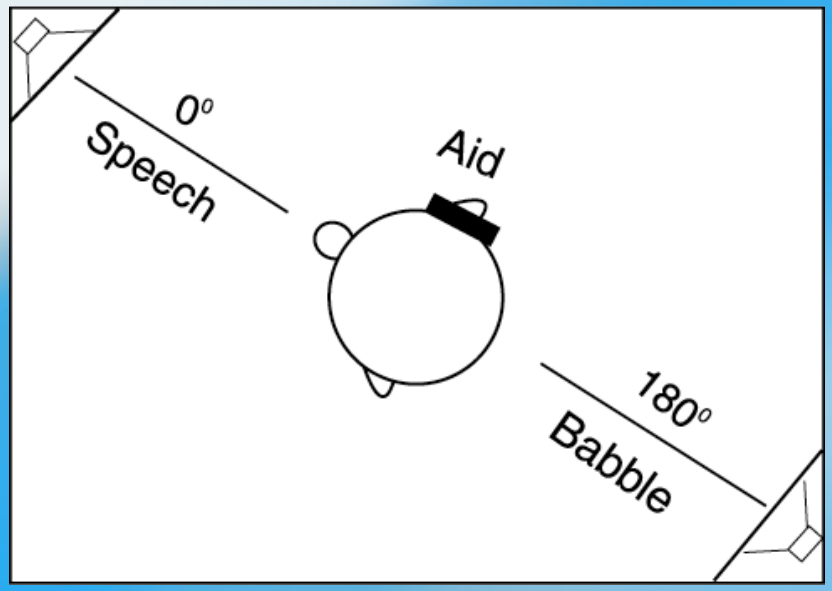




Split Track: Test Setup

Results reflect location of SF loudspeakers and the directional mic's polar pattern

Be aware of the limitations of any tests done in a sound booth

Mount the "noise" speaker on the ceiling?

ETYMŌTIC RESEARCH INC.

Example 1: Separated Lists

	Channel 1	Channel 2	
	Dial (dB HL)	Dial (dB HL)	SNR (dB)
Sentence 1	70	45	25
Sentence 2	70	50	20
Sentence 3	70	55	15
Sentence 4	70	60	10

Scoring: 25.5 – Total Correct = SNR Loss

ETYMOTIC RESEARCH INC.

Example 2: Separated Lists

	Channel 1	Channel 2	
	Dial (dB HL)	Dial (dB HL)	SNR (dB)
Sentence 1	70	55	15
Sentence 2	70	60	10
Sentence 3	70	65	5
Sentence 4	70	70	0

Scoring: 15.5 – Total Correct = SNR Loss

ETYMOTIC RESEARCH INC.

QuickSIN Statistics: Comparing Two Conditions

Lists per Condition	1	2	3	4	5	6	7	8	9
95% C.D. ±, in dB	3.9	2.7	2.2	1.9	1.7	1.6	1.5	1.4	1.3
90% C.D. ±, in dB	3.2	2.2	1.8	1.6	1.4	1.3	1.2	1.1	1.1
80% C.D. ±, in dB	2.5	1.8	1.5	1.3	1.1	1.0	1.0	0.9	0.8

ETYMOTIC RESEARCH INC.

QuickSIN Use

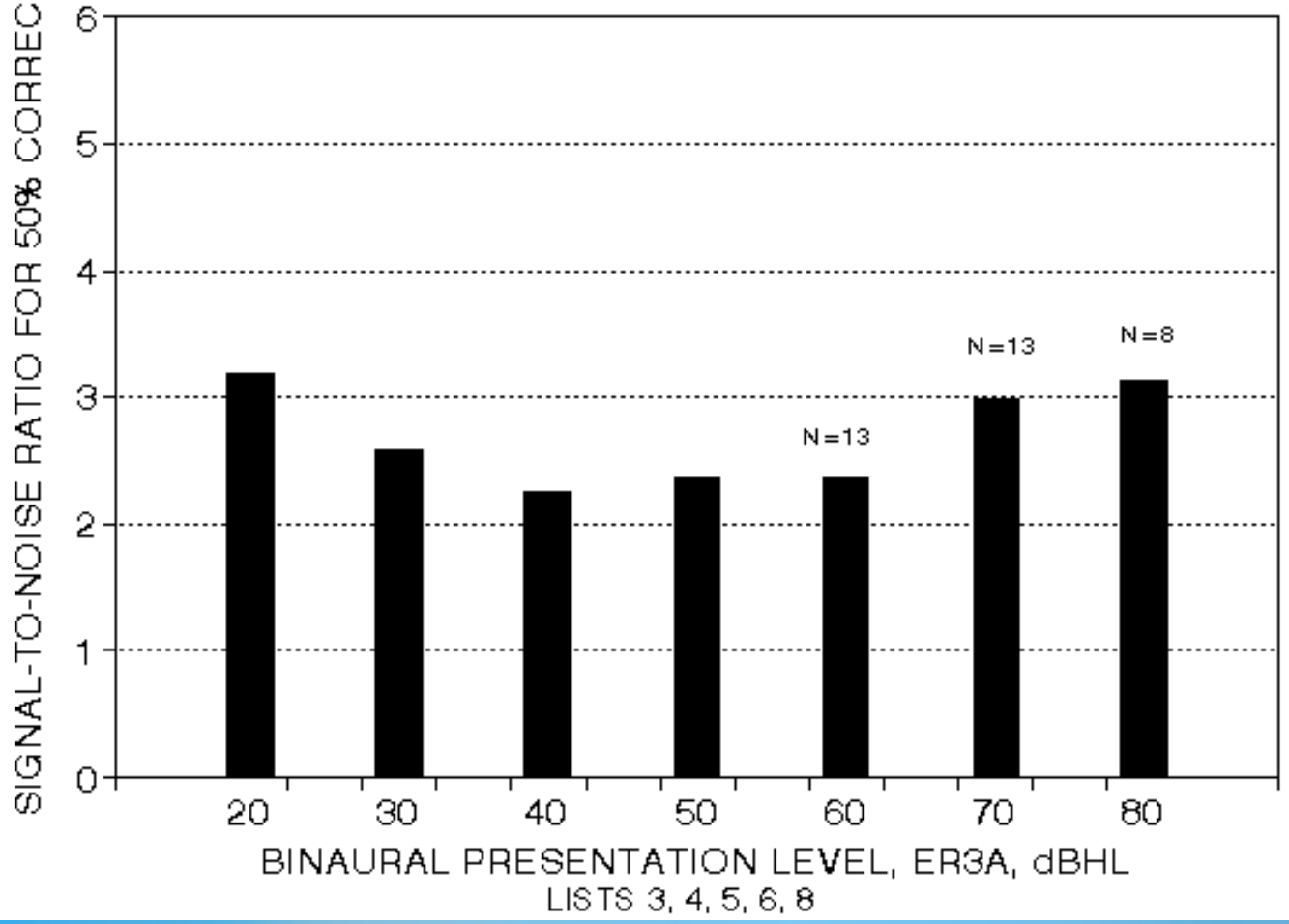
- Measure SNR Loss, unaided
  - As part of the diagnostic test battery, to estimate the ability to hear in noise
  - Use results to select amplification / ALDs
  - Basis for counseling re: realistic expectations
- Measure SNR Loss, unaided vs. aided
  - In SF, at 70 dB HL, unaided then aided
  - Performance shouldn’t decrease in the aided condition

QuickSIN use (cont.)

- Demonstrate aided benefit
  - Low presentation level in SF, unaided vs. aided
- Demonstrate SNR improvements
  - 70 dB HL in SF, separate-track version

SIN TEST: SNR-50 vs PRESENTATION LEVEL

NH SUBJECTS (N=14) NIQUETTE, 1998



ETYMŌTIC RESEARCH INC.

BKB-SIN™ Test

- Why develop another test?
  - Length of IEEE sentences problematic for elderly with auditory memory deficits
  - IEEE sentences too difficult for young children
  - Cochlear Americas: Binaural CI study

ETYMŌTIC RESEARCH INC.

BKB-SIN™ Test

- Bamford-Kowal-Bench (BKB) sentences in Auditec 4-talker babble
  - Shorter, simpler sentences (approximately first grade language level)
  - 3 to 4 key words per sentence
  - Male talker; verbal “ready” cue spoken prior to each sentence
  - One sentence at each SNR of:
    21, 18, 15, 12, 9, 6, 3, 0, -3, -6 dB

ETYMŌTIC RESEARCH INC.

BKB-SIN Phase 1: Recordings

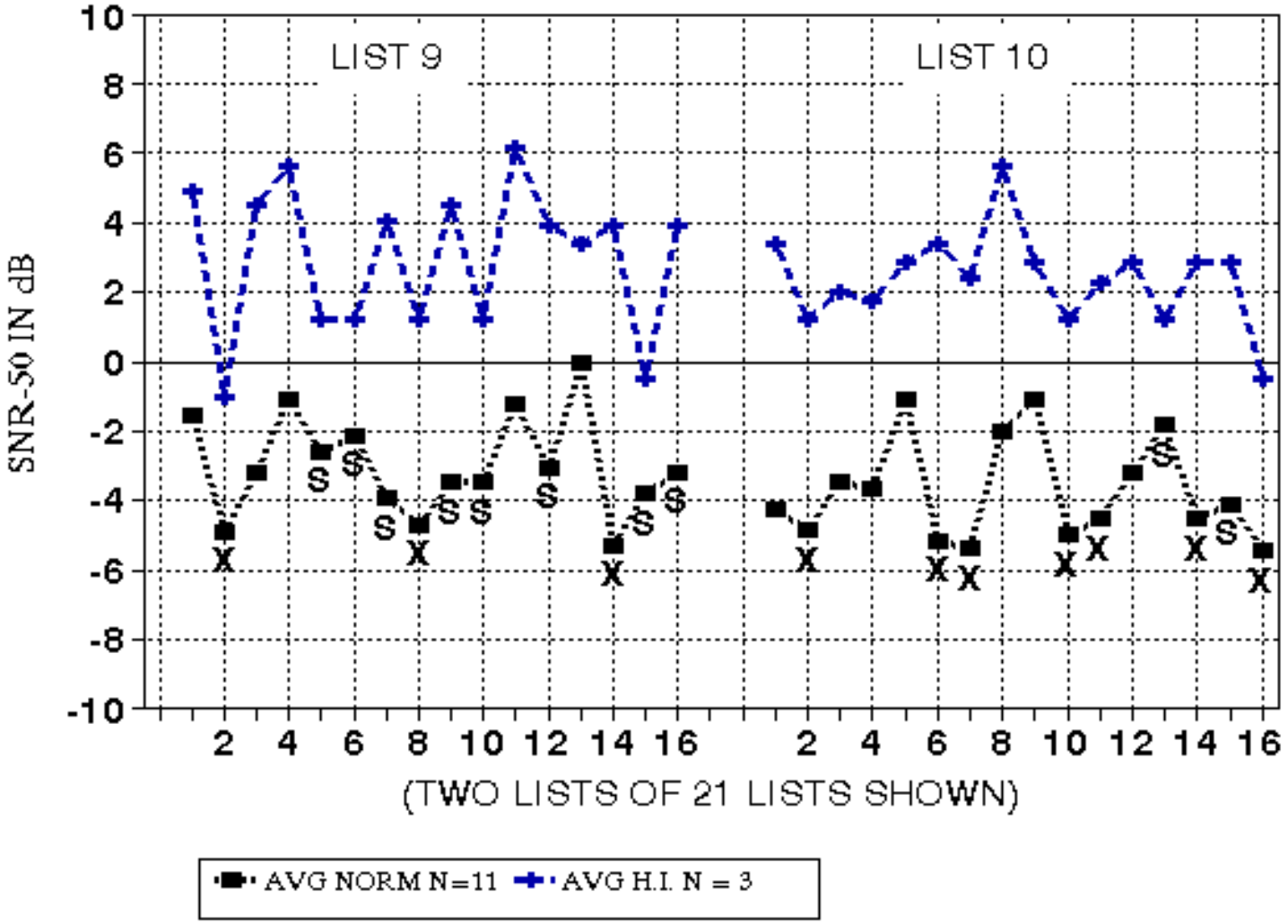
- Digital recording of BKB sentences provided by Margo Skinner (NIDCD grant #R01 DC00581).
- Sentences spoken by Jon Shallop, engineered by Kenneth Plantel
- RMS level of each sentence in each list was equalized

Phase 1: Sentence Equivalence

- Does RMS equivalence = sentence equivalence?
  - Some sentences are easier, others more difficult, when presented in 4-talker babble
  - Ebb and flow of babble affects masking; each sentence time-locked to its babble segment
  - Phase 1 data (BKB sentences in 4-talker babble) obtained on adult normal-hearing and hearing-impaired subjects

BKB DEVELOPMENT PHASE 1 RECORDINGS

SNR-50 FOR 11 NORMAL AND 3 H.IMP Ss



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BKB-SIN Test Format

- 3 minutes per List Pair
- 18 List Pairs:
  - 8 List Pairs for use with NH and HI adults, NH and HI children (to –6 dB SNR)
  - Additional 10 list pairs for HI adults and children (to 0 dB SNR)

List 1A (Track 1)	Key Words	# Correct	SNR
1. They are looking at the clock.	4	_____	+21 dB
2. The car engine is running.	3	_____	+18 dB
3. Children like strawberries.	3	_____	+15 dB
4. They are buying some bread.	3	_____	+12 dB
5. The green tomatoes are small.	3	_____	+9 dB
6. He played with his train.	3	_____	+6 dB
7. The bag fell to the ground.	3	_____	+3 dB
8. The boy did a handstand.	3	_____	0 dB
9. The water boiled quickly.	3	_____	-3 dB
10. The man is painting a sign.	3	_____	-6 dB
	Total Key Words Correct	_____	
	SNR–50 = (23.5) - (# Correct) =	_____dB	

List 1B	Key Words	# Correct	SNR
1. The dog made an angry noise.	4	_____	+21 dB
2. They followed the path.	3	_____	+18 dB
3. Someone is crossing the road.	3	_____	+15 dB
4. The mailman brought a letter.	3	_____	+12 dB
5. The milk was by the front door.	3	_____	+9 dB
6. The candy shop was empty.	3	_____	+6 dB
7. The lady stayed for lunch.	3	_____	+3 dB
8. The policeman knows the way.	3	_____	0 dB
9. The little girl was happy.	3	_____	-3 dB
10. They are coming for Christmas.	3	_____	-6 dB
	Total Key Words Correct	_____	
	SNR–50 = (23.5) - (# Correct) =	_____dB	

Average SNR–50, Lists 1A and 1B = _____dB

ETYMŌTIC RESEARCH INC.

BKB-SIN Demo (List 6A)

		SNR	Correct
1.	A boy ran down the path.	21dB	4
2.	The orange was very sweet.	18 dB	3
3.	He is holding his nose.	15 dB	3
4.	The new road is on the map.	12 dB	3
5.	The boy forgot his book.	9 dB	3
6.	A friend came for lunch.	6 dB	2
7.	The match boxes are empty.	3 dB	1
8.	The family bought a house.	0 dB	0
9.	The ball broke the window.	-3 dB	0
10.	The pond water is dirty.	-6 dB	0

SNR-50 = 23.5 – 19 = 4.5

SNR Loss: See age-related norms

ETYMŌTIC RESEARCH INC.

BKB-SIN: Reliability (NH Adults)

Number of Lists	1	2	3	4	5	6	7	8	9
95% C.I. ±, in dB	1.6	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.5
90% C.I. ±, in dB	1.3	0.9	0.7	0.6	0.6	0.5	0.5	0.5	0.4
80% C.I. ±, in dB	1.0	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3

ETYMŌTIC RESEARCH INC.

BKB-SIN: Critical Differences for Comparisons (NH Adults)

Lists per Condition	1	2	3	4	5	6	7	8	9
95% C.D. ±, in dB	2.2	1.6	1.3	1.1	1.0	0.9	0.8	0.8	0.7
90% C.D. ±, in dB	1.8	1.3	1.0	0.9	0.8	0.7	0.7	0.6	0.6
80% C.D. ±, in dB	1.4	1.0	0.8	0.7	0.6	0.6	0.5	0.5	0.5

ETYMOTIC RESEARCH INC.

BKB-SIN Test

- Norms for adults, children, CI users
- Two-CD Set:
  - Combined tracks
  - Split tracks

ETYMOTIC RESEARCH INC.

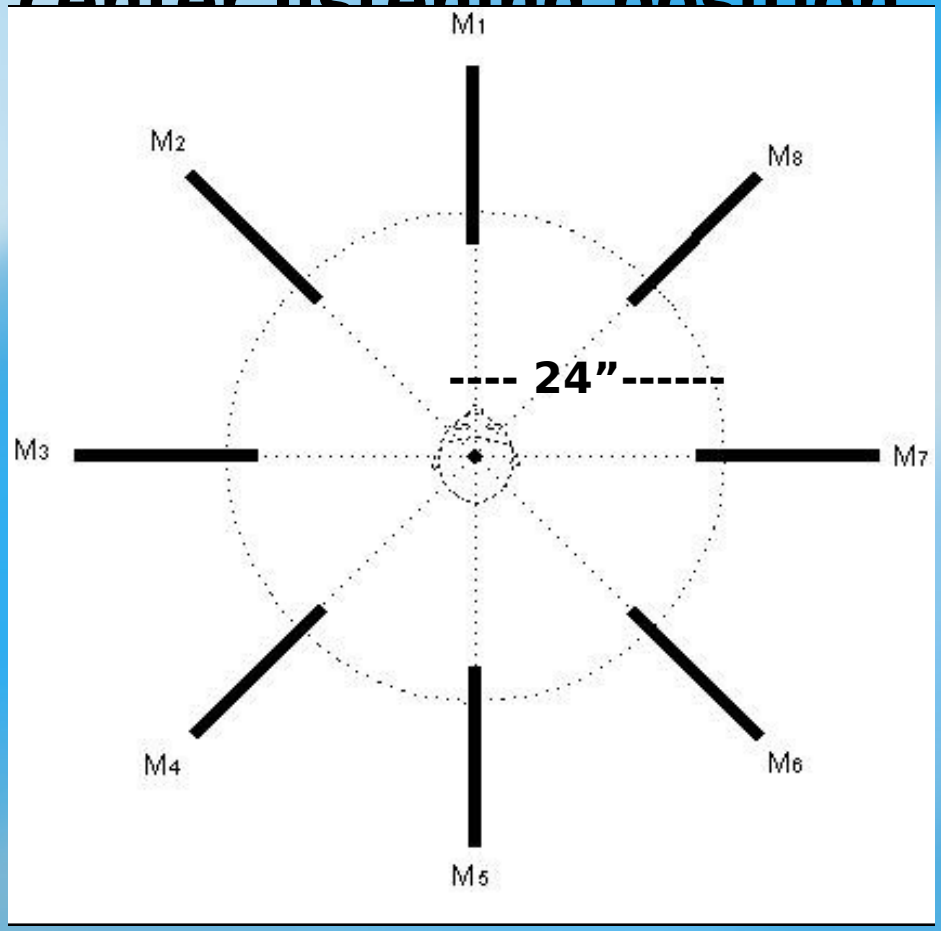
R-Space™ Sound System

- Joint development between Etymotic Research and Revitronix
- Sound recording and playback system for accurate simulation of real-world acoustic environments
- Laboratory control and repeatability

ETYMŌTIC RESEARCH INC.

RECORDING SYSTEM

A multiple “long-gun” microphone array captures environmental sounds from all horizontal directions,before the sounds reach the center listening position.



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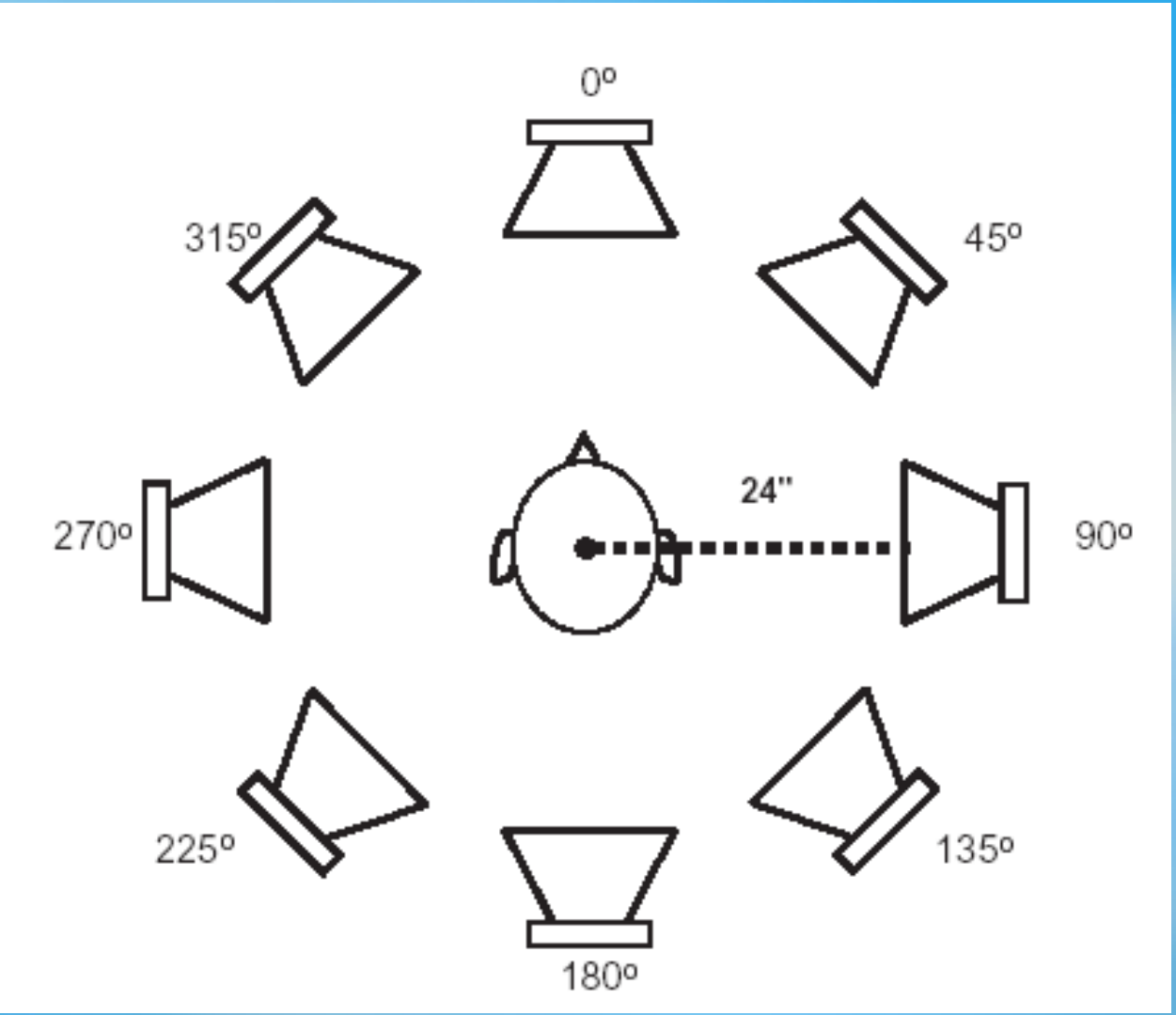
Lou Malnati's Restaurant with long-gun recording mic array and KEMAR

ETYMŌTIC RESEARCH INC.

R-SPACE™ Playback System



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R-SPACE Playback System at Etymotic Research

ETYMŌTIC RESEARCH INC.

R-Space Goals:

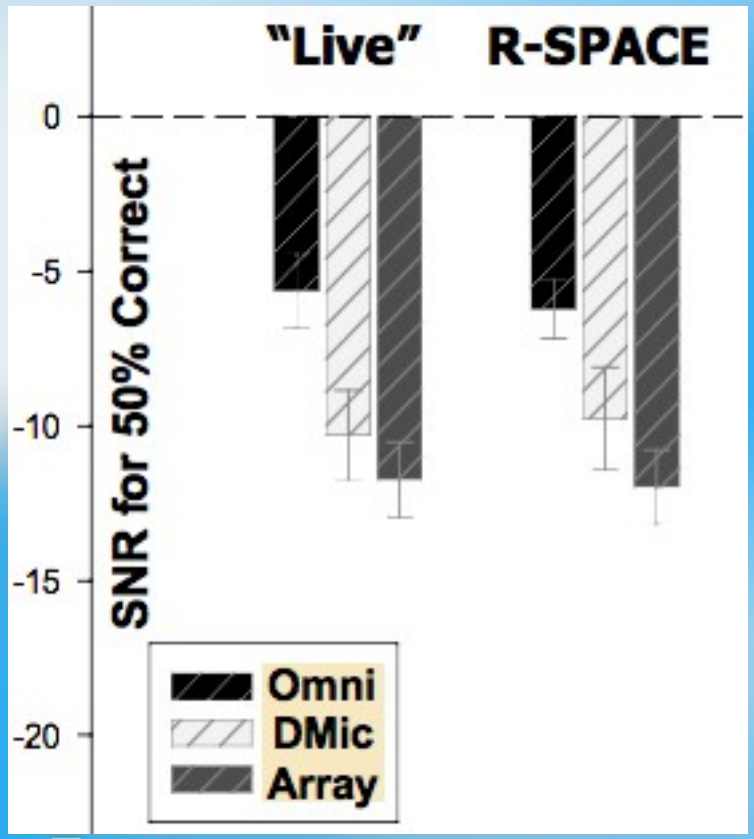
- The simulated environments should sound real.

- The simulated environments should allow the hearing mechanism and hearing aids to perform as they do in the real world.

- Study needed to confirm or disprove that R-Space results accurately predict real-world results.

ETYMŌTIC RESEARCH

Compton-Conley et. al., 2004: Performance of directional microphones for hearing aids: real-world versus simulation. *J. Amer. Acad. of Audiology*. 15 (6) 440-455).



- Performance in the R-SPACE condition was not significantly different from performance in the "live restaurant" condition

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Evaluating Auditory Fitness for Duty

- Tools exist for measuring the “hearing in noise” component
  - Learn all you can about each tool
  - Learn how to apply them and what the results mean for your specific situation
    - What does the person need to hear?
    - Under what conditions?
    - What are the ramifications?
  - Be aware of the benefits and limitations of the available tools
  - If necessary, experiment and modify the application of the tools to suit your needs (you may need to create your own norms!)

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